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Design of SVPWM Inverter for Induction Motor Drive Using Neural Network Predictive Control

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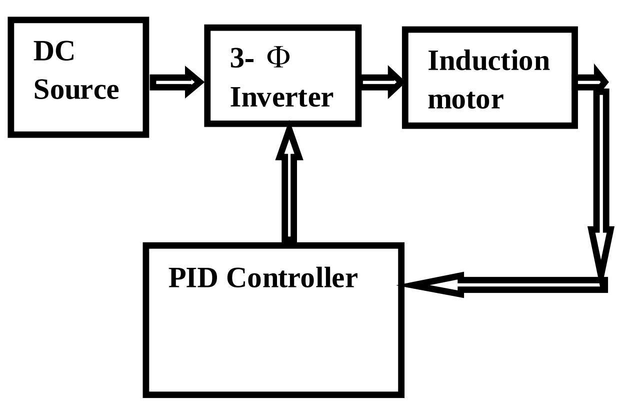
Abstract*: This paper presents a neural network predictive controller for three phase inverter fed induction machine speed control. Thus the three phase inverter fed induction motor drive has been simulated with and without step change using NNP controller and the results are compared with PID controller. The performance comparisons of conventional PID and Neural network predictive controller are achieved with the help of IAE (Integral absolute error) and ITAE (Integral time-weighted absolute error).
Keywords: NNP and PID controller, Integral absolute error, and Integral time-weighted absolute error

I. INTRODUCTION

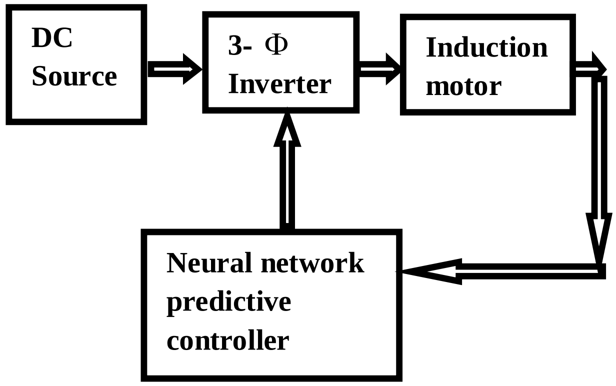
Nowadays, induction motor plays a vital role in industrial purposes. As compared to DC machine, it gives less cost and easy maintenance. However, the speed control of induction motor is more complex, which gives non-linear in nature. Therefore, speed variation can be achieved for this kind of machine by acting on the supply net frequency. There is no effective and simple way to vary the frequency of a supply until the present power electronics were developed. On the other hand, in electric traction, the use of power is either DC or AC. Three phase DC/AC inverter is the only possible interface due to their flexible voltage and frequency variation. As mentioned above, a three phase DC/AC inverter used in traction is supplied by power either in AC or DC In the case of AC supply, it is directly connected to the three phase DC/AC inverter through step up/down transformer and an AC/DC rectifier. The control problem in the induction motor is to design a controller ensuring a wide range of speed point for a three phase system and induction motor In the present work, a PID controller is designed to control the motor speed by varying its reference value and to regulate the motor speed. To overcome the drawbacks of PID controller, we move on to neural network predictive controller. It will be formally proved that the compared to PID controller, NNP controller actually stabilizes the controlled system and does meet its tracking objectives with a good accuracy.

II. METHODOLOGY

The block diagram of the proposed work for both PID controller and neural network predictive controller is shown in fig 1. The block diagram consists of DC supply as voltage source which is connected to a three-phase IGBT based inverter which is fed to an induction motor. A conventional PID and NNP controller is used for the control of triggering pulse of inverter switch. By varying the triggering pulse of the inverter a constant (V\F) ratio is maintained for obtaining the speed of the induction motor.



(a)



(b)
Fig 1 (a), (b): Overall Block diagram of proposed technique

The inverter used here is a three phase IGBT inverter which has the ability of decreasing and increasing the output voltage according to the requirement. The usage of inverter allocates the operation of induction machine even in low load conditions. The intelligent controller used is Neural network predictive controller as shown in fig 1(b) which comprises the advantage of handling any type of self-tuning capabilities, information, self-learning, mimic human decision making process and self organizing etc which helps to control the induction motor more accurately when compare to conventional PID controller.

III. SPACE VECTOR MODULATION

the SVPWM algorithm, the d-axis and q-axis voltages are converted into three phase instantaneous reference voltages. The unreal switching time periods relative to the instantaneous values of the reference phase voltages and can be defined as

$$V_\alpha + jV_\beta = \frac{2}{3}\left(V_a + e^{\frac{j2\pi}{3}}V_b + e^{\frac{-j2\pi}{3}}V_c\right) \quad (1)$$

A. Realization of Space Vector PWM

1) Step 1. Determine V_d, V_q, V_{ref}, and angle (α)
2) Step 2. Determine time duration T_1, T_2, T_0
3) Step 3. Determine the switching time of each transistor (S_1 to S_6)

Vref can be initiating with one zero vector and two active. For sector 1 (0 to $\pi/3$): Vref can be located with V0, V1 and V2. Vref in terms of the duration time can be considered as:

$$V_{ref} * T_c = V_1\frac{T_1}{T_c} + V_2\frac{T_2}{T_c} + V_0\frac{T_0}{T_c} \quad (2)$$

$$V_{ref} = V_1T_1 + V_2T_2 + V_0T_0 \quad (3)$$

The total cycle is given by:

$$T_c = T_1 + T_2 + T_0 \quad (4)$$

The position of Vref, V_1, V_2 and V_0 can be described with its magnitude and angle:

$$V_{ref} = V_{ref}r^{j\theta} \quad (5)$$

$$V_1 = \frac{2}{3}V_{DC} \quad (6)$$

$$V_2 = \frac{2}{3}V_{DC}e^{\frac{j2\pi}{3}} \quad (7)$$

$$V_o=0 \tag{8}$$

$$T_c = \begin{pmatrix}\cos\theta \\ \sin\theta\end{pmatrix} T_1 \left(\frac{2}{3}\right) V_{DC} \begin{pmatrix}1 \\ 0\end{pmatrix} + T_2 \left(\frac{2}{3}\right) V_{DC} \begin{pmatrix}\cos\left(\frac{\pi}{3}\right) \\ \cos\left(\frac{\pi}{3}\right)\end{pmatrix} \tag{9}$$

Dividing these in real and imaginary parts simplifies the calculation for each duration time:

Real part:

$$T_c V_{ref} cos\theta = T_1 \left(\frac{2}{3}\right) V_{DC} + T_2 \left(\frac{1}{3}\right) V_{DC} \tag{10}$$

Imaginary part:

$$T_c V_{ref}\, sin\theta = T_2 \left(\frac{1}{\sqrt{3}}\right) V_{DC} \tag{11}$$

T1 and T2 are then given by:

$$T_1 = T_c \frac{\sqrt{3}\, V_{ref}}{V_{DC}} \sin\left(\frac{\pi}{3} - \theta\right) \tag{12}$$

$$= T_c . a. \sin\left(\frac{\pi}{3} - \theta\right) \tag{13}$$

$$T_2 = T_c \frac{\sqrt{3}\, V_{ref}}{V_{DC}} \sin(\theta) \tag{14}$$

$$= a. \sin(\theta) \quad 0 < \theta < \frac{\pi}{3} \tag{15}$$

IV. CONTROLLER DESIGN

A. Neural Network Predictive Controller

This predictive controller uses a neural network for a non-linear model to predict the system future performance. The NNP controller calculates the controlled inputs that will optimize the system performance beyond a particular future time horizon. The early step in the predictive control is to estimate the neural network system model. Second step is the system model is used by the predictive controller to predict the future performance of the given system. The NNP controller uses the previous input and output to predict the future values of the system. The outlook of the neural network system model is given in the fig 2.

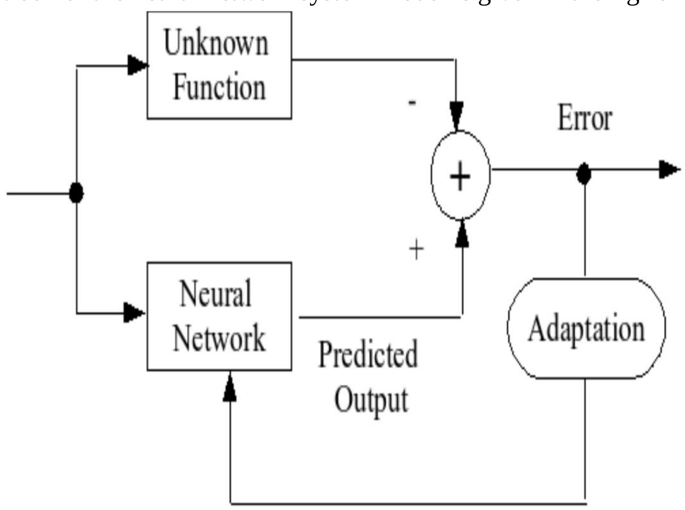


Fig: 2 Structure of NNP controller

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The aim approach which is used by the NNP control is to calculate the future response of the system and to eliminate the price utility based on the error between the predicted response of the system and the reference path. The price utility, which may be dissimilar from case to case, in order to get the best control input which is given to the non-linear system.

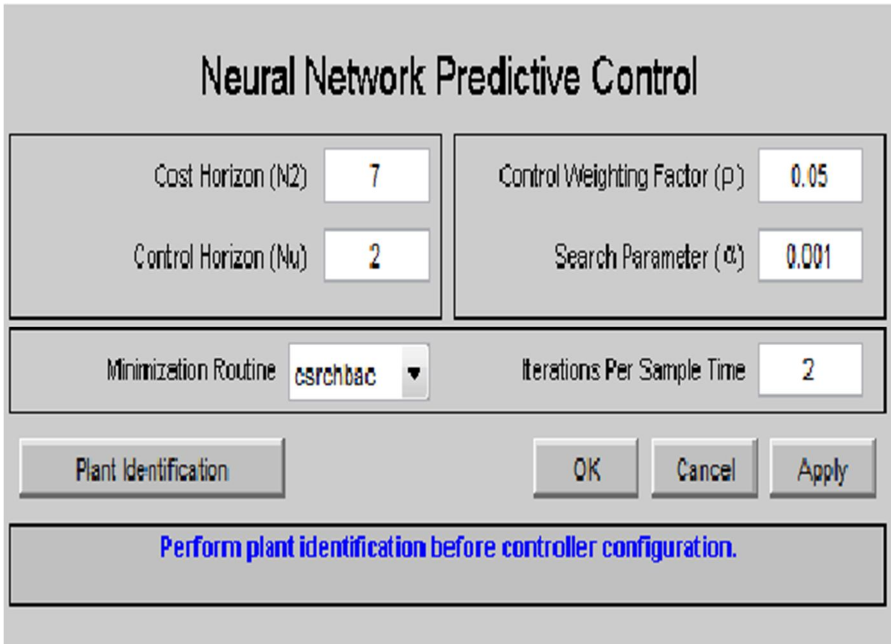

Fig: 3 neural network predictive control

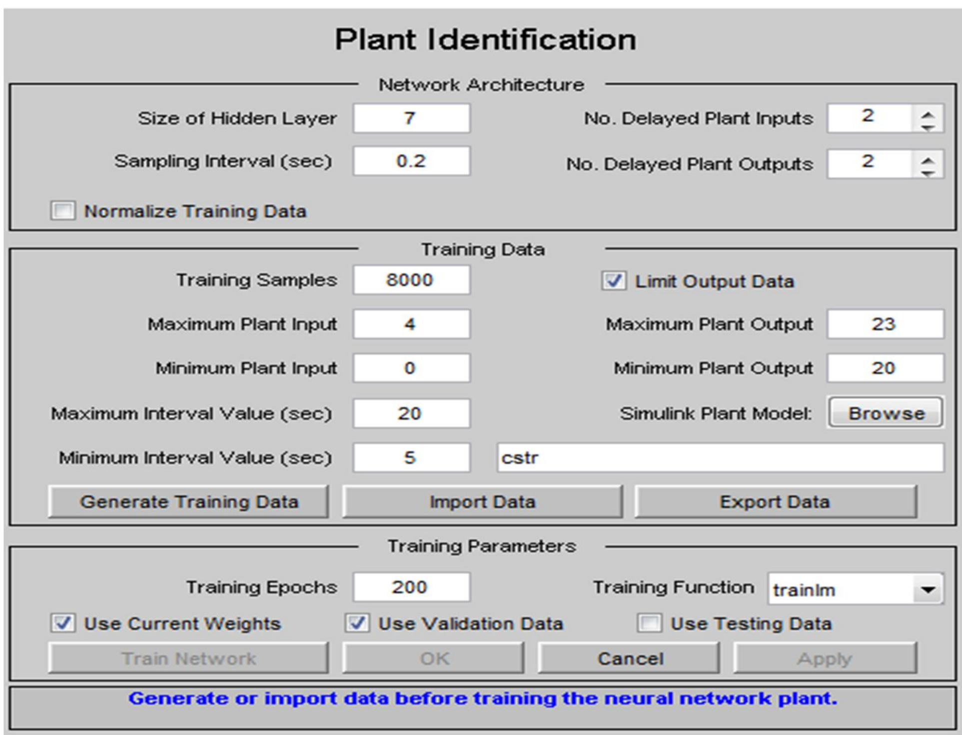

Fig: 4 Plant identification for neural network predictive controller

With the large amount of data, neural network are used for training. The way of training the network is much easier than any other system. The other parameters are determined from actual system necessities. The main significant is to train the network and control the speed of the motor. The various specification need for system model is shown in fig 5.

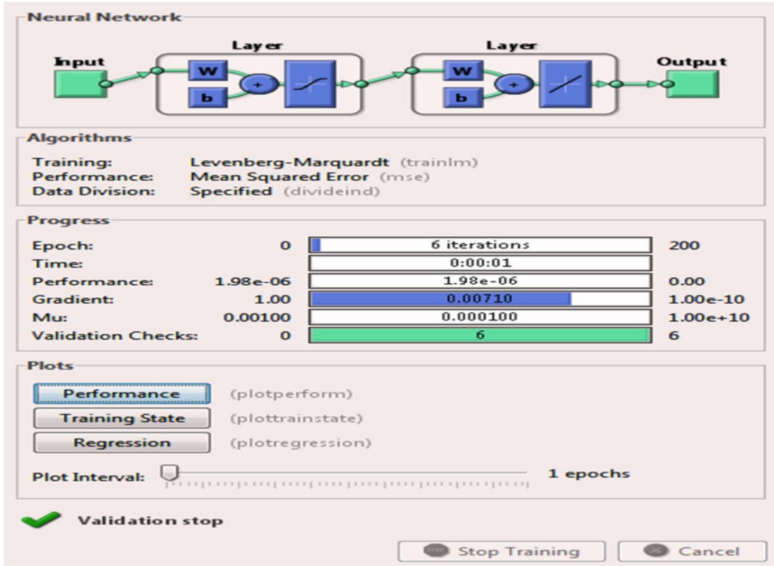

Fig: 5 Plant identification

V. RESULTS AND DISCUSSION

The Matlab/Simulation results are shown in the following figures 6-9. Simulation is performed for the proposed circuit with MATLAB/SIMULINK version R2010a. The response of induction motor with NNP controller is shown in the figures 8(b) and 9(b). The output voltage of three phase inverter Va, Vb, Vc which is shown in fig 6 gives the maximum output voltage of 520 V. The switching pattern of SVPWM for inverter fed induction motor drive is shown in fig: The reference value speed is considered as 1000 rpm for Simulation results which are obtained under different operating conditions. The results obtained with the PID controlled and NNP controlled drive is given in Figures 8 and 9. The performance of the drive during Step change in speed and load torque with PID and NNP controller (load torque of 11 N-m is applied at 0.5 sec and removed at 1.5 sec) is shown Figure 8 (a) and 8 (b). The steady state phase response is shown in Figure 9 (a) and 9 (b). It is observed that the ripple content in the current wave forms are less, the torque ripple reduced with NNP controller.

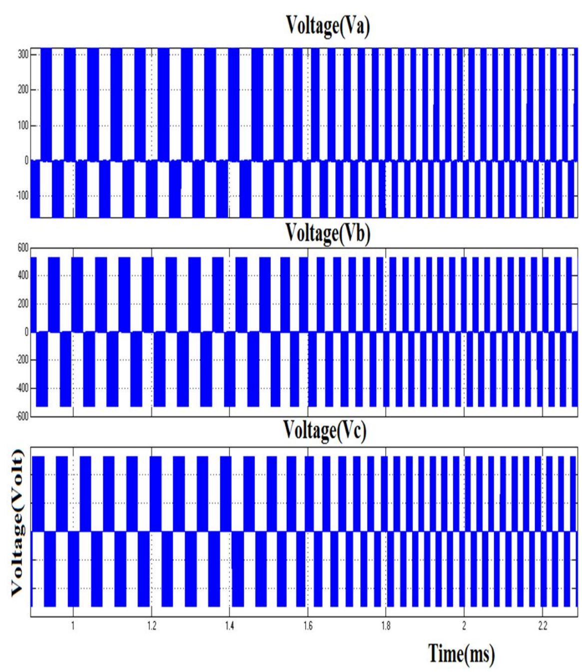

Fig: 6 Inverter output voltages

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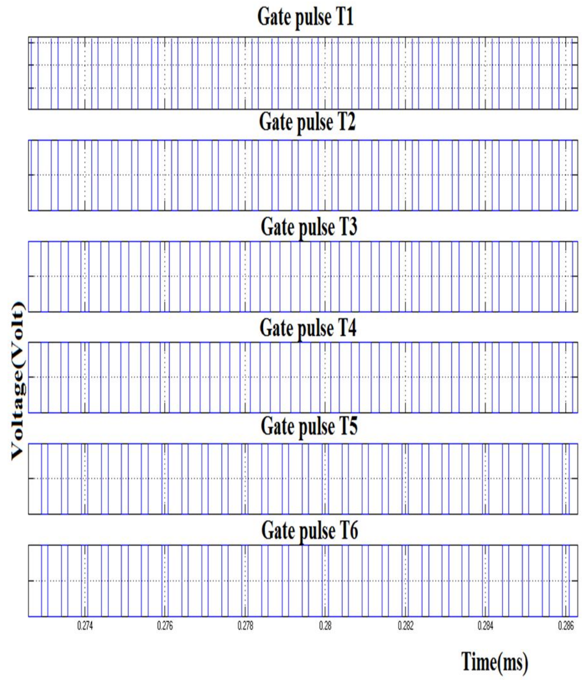
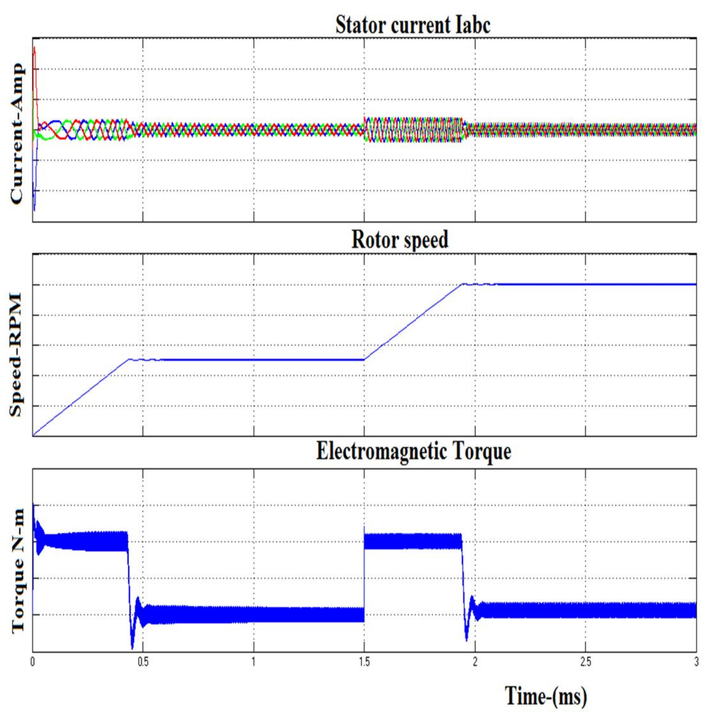


Fig: 7 switching pattern of SVPWM for inverter fed induction motor drive



(a) With PID controller

Fig: 8 Performance of induction motor with step change in load torque and speed (a) with PID controller (b) with NNP controller

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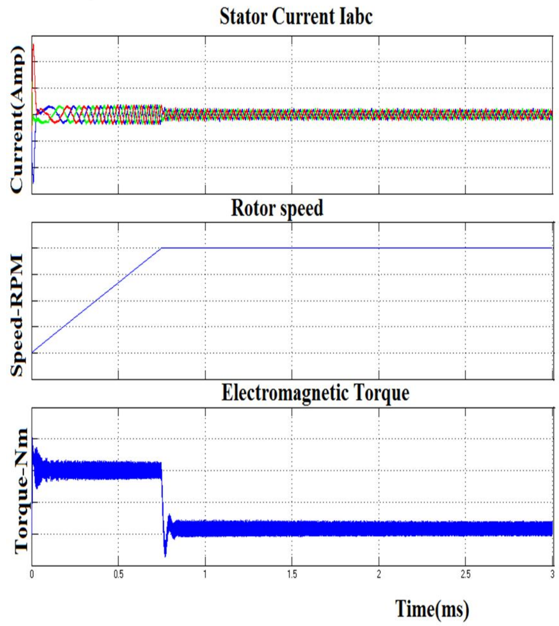
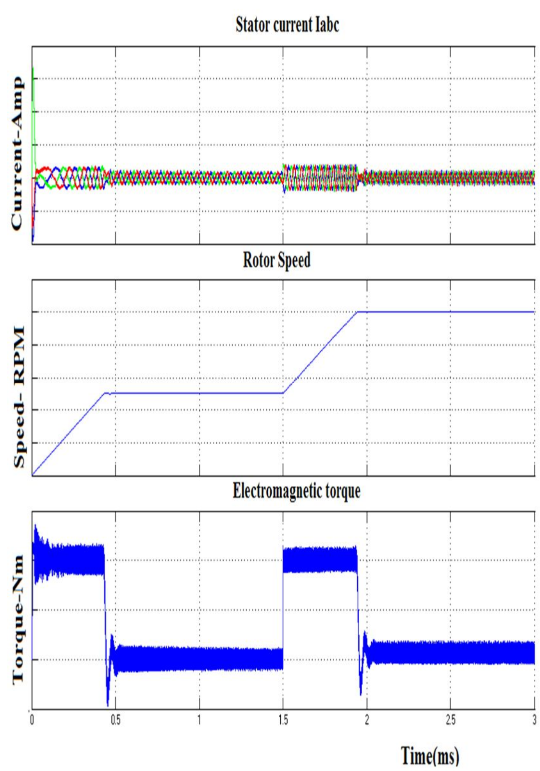
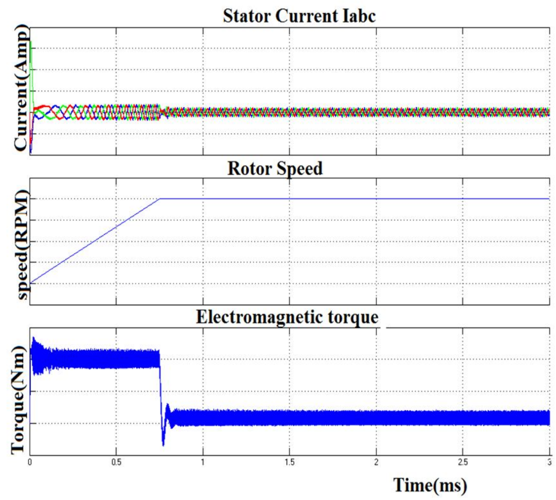


(a) With PID controller

(b) Fig: 9 Performance of induction motor without step change in load torque and speed (a) with PID controller
(c) (b) With NNP controller



(b) With NNP controller



(d) With NNP controller
(a) With NNP controller

A. Performance Comparison Of Pid And Neural Network Predictive Controller

The performance comparison of PID and Neural network predictive controller is achieved with the help of IAE (Integral absolute error) and ITAE (Integral time-weighted absolute error). The IAE and ITAE values of NN predictive controller for induction motor drive are very less when compare to PID fed induction motor drive. The performance comparison is shown in table 1.

Table: 1 performance comparison of PID and NNP controller

Controller	IAE	ITAE
PID	212.7	391.7
Neural network predictive controller	41.02	47.28

VI. CONCLUSION

This paper presents a comparative analysis of PID and Neural network predictive controller. In large perspective the overall performance of a drive under different operating conditions is improved with neural network predictive controller compared to conventional PID controller. The performance comparisons of conventional PID and Neural network predictive controller are achieved with the help of IAE (Integral absolute error) and ITAE (Integral time-weighted absolute error). It has been formally established that the controllers actually meets the performance comparisons which is shown in table 1 and it has been designed to achieve, satisfactory rotor speed reference tracking over a wide range of speed reference variation. These results have been confirmed by a simulation study.

APPENDIX

Parameters	Rated values
Power	50 hp
Voltage	460 V
Frequency	60 Hz
Stator/rotor resistances	0.087/0.228 Ω
Stator/rotor inductances	0.8e-3 H
Mutual inductance	34.7e-3 H
Pole pairs	2
Inertia	1.662 J

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